Determining the daytime Earth's Radiation Budget from DSCOVR

Wenying Su
NASA Langley Research Center, Hampton, VA

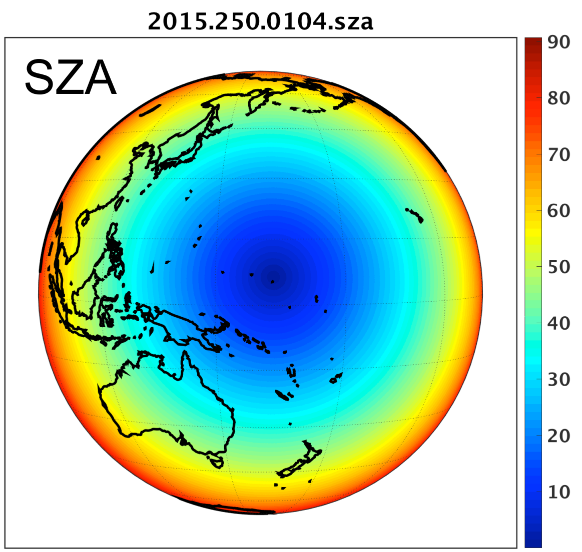
L. Liang, P. Minnis, D. P. Duda, K. Khlopenkov, M. K. Thiemann
SSAI, Hampton VA

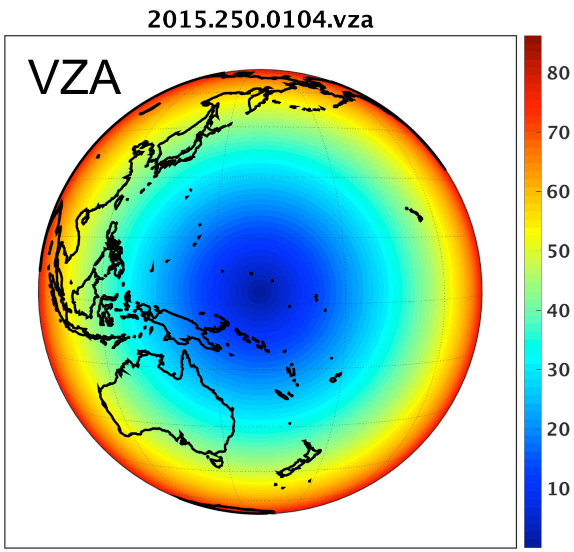
National Institute of Standards and Technology Advanced Radiometer

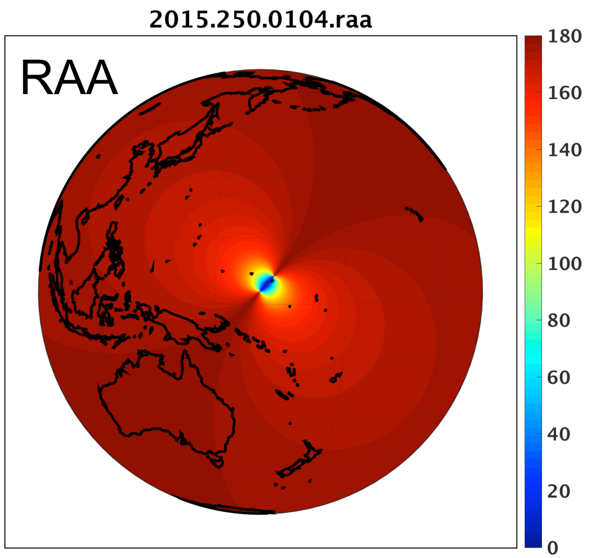
- NISTAR on board DSCOVR provides continuous broadband irradiance measurements over the sunlit side of the Earth using active cavity radiometers for three channels: shortwave (SW, 0.2-4.0 μm), near-infrared (NIR, 0.7-4.0 μm), and total (0.2-100 μm).

NISTAR uncertainty estimates for 4hr mean (provided by Yinan Yu from L-1)

(%)	Instr. noise	Stability	Lab cal	Total (%, 1σ)
Total	1.2	0.3	<0.2	1.3
SW	1.7	0.3	1	2.0
NIR	5.5	0.3	1	5.6

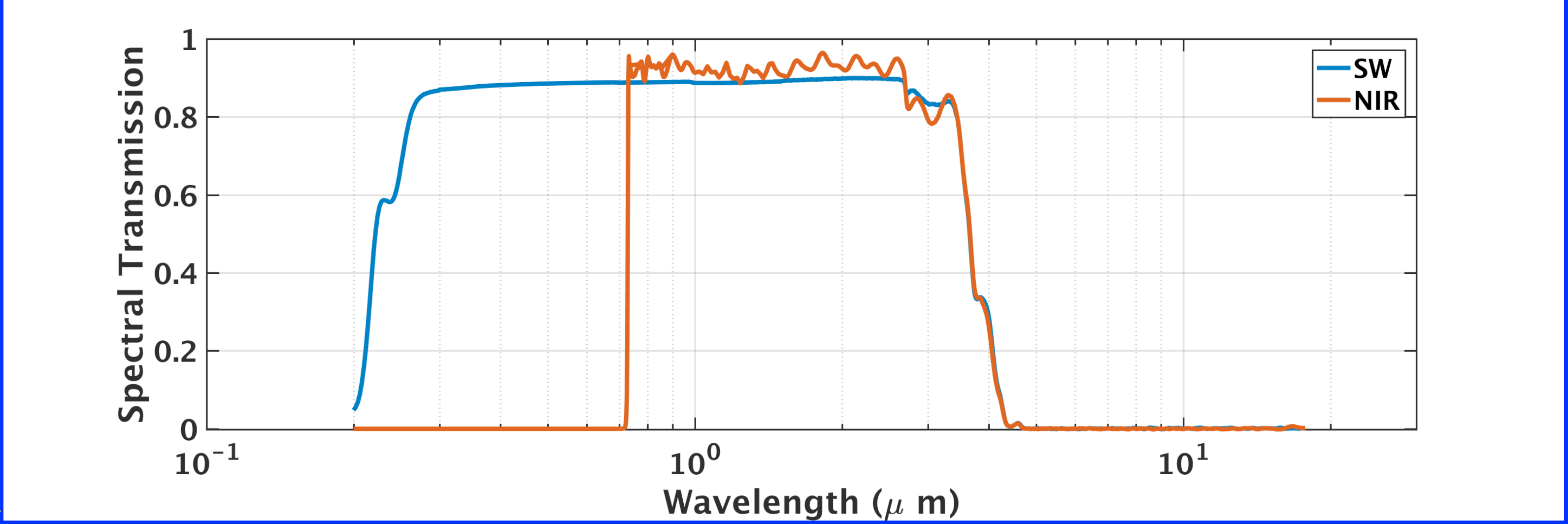




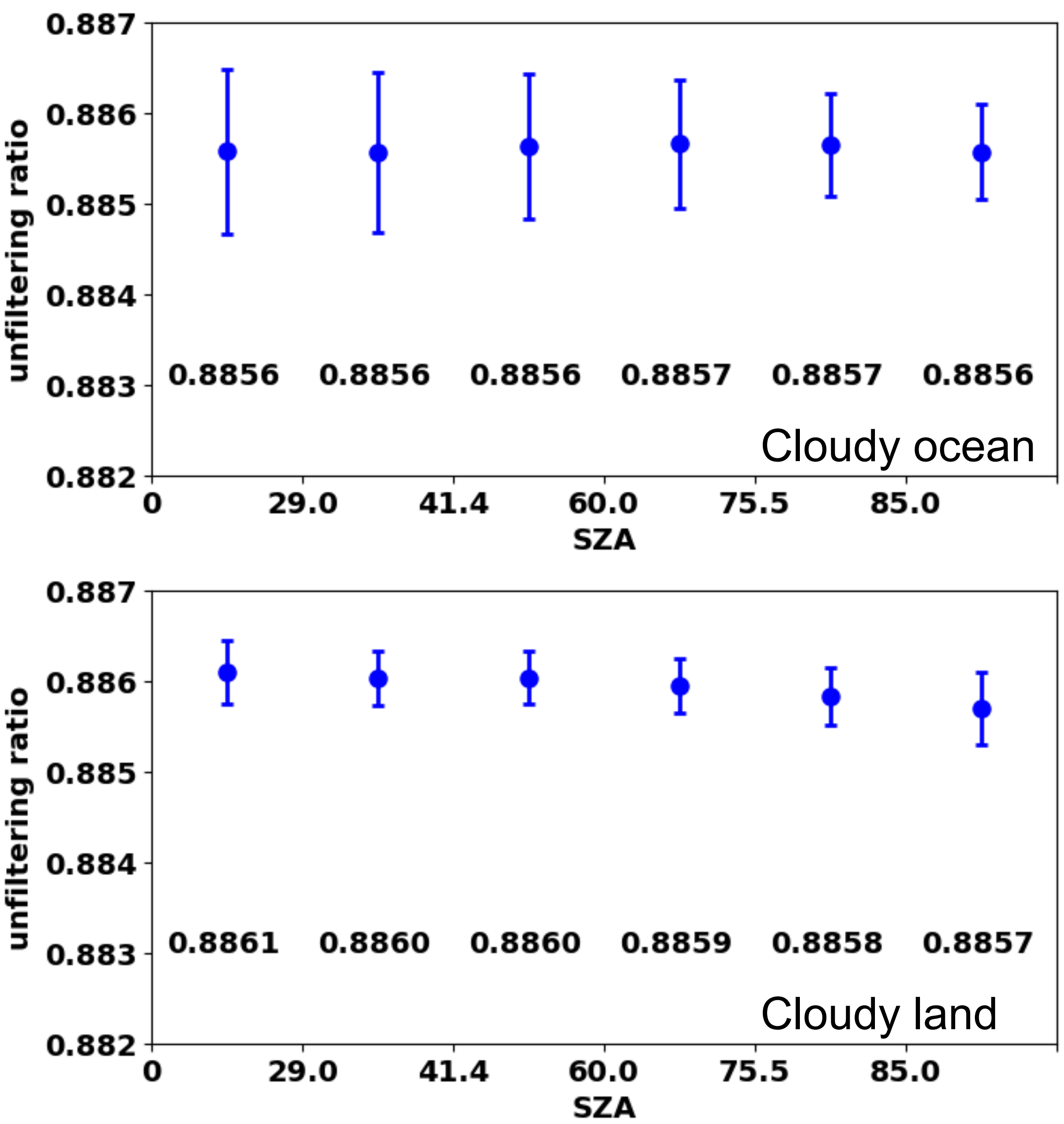


Unfilter of the NISTAR SW data

- Filters are placed in front of the cavity radiometers to measure the energies from the SW/NIR portion of the spectrum.
- The detector measures the filtered radiances pass through the spectral filter: $$I_f^{band} = \int_{\lambda_1}^{\lambda_2} S_\lambda^{band} I_\lambda d\lambda$$
- Unfiltered radiances: $$I_u^{band} = \int_{\lambda_1}^{\lambda_2} I_\lambda d\lambda$$
- Relationship between filtered and unfiltered radiances are determined from theoretically derived values simulated for typical Earth scenes and the NISTAR spectral transmission functions.



SW ratio $\kappa = I_f / I_u$ over cloudy ocean/land



- The mean ratio over cloudy ocean is 0.8856 (a total of 15680 cases).

- The mean ratio over cloudy land is 0.8859 (a total of 58800 cases).

Deriving daytime SW and LW flux from NISTAR

- Derive the unfiltered SW radiance:

$$I_u^{sw} = I_f^{sw} / \kappa^{sw}$$

- Derive the LW radiances:

$$I_u^{lw} = I^{tot} - I_u^{sw}$$

- Convert the SW radiance to flux:

$$F_n^{sw} = \frac{\pi I_u^{sw}}{\overline{R_{sw}}}$$

$\overline{R_{sw}}$ is the global mean SW anisotropic factor for the NISTAR view

- Convert the LW radiance to flux:

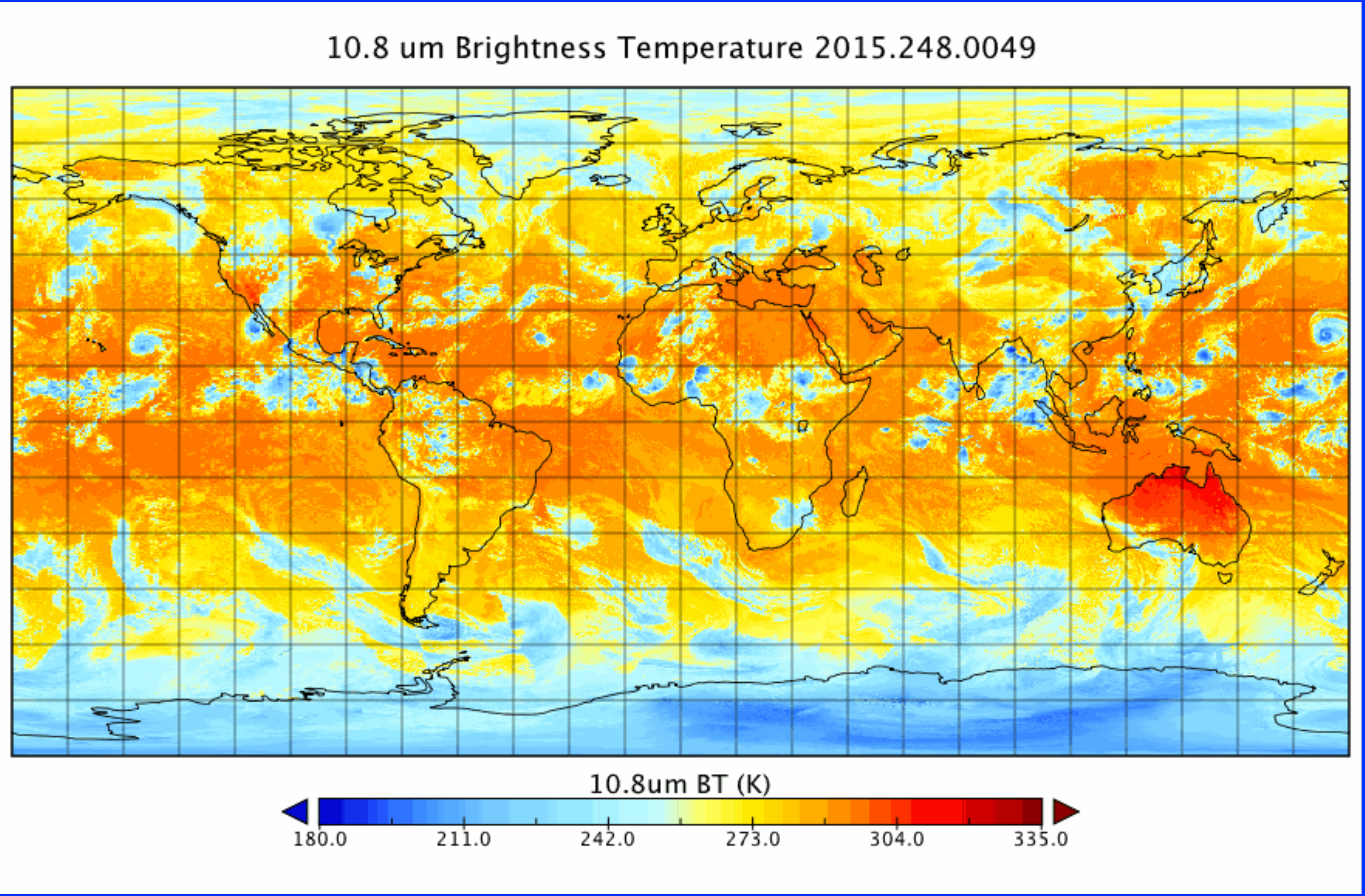
$$F_n^{lw} = \frac{\pi I_u^{lw}}{\overline{R_{lw}}}$$

$\overline{R_{lw}}$ is the global mean LW anisotropic factor for the NISTAR view

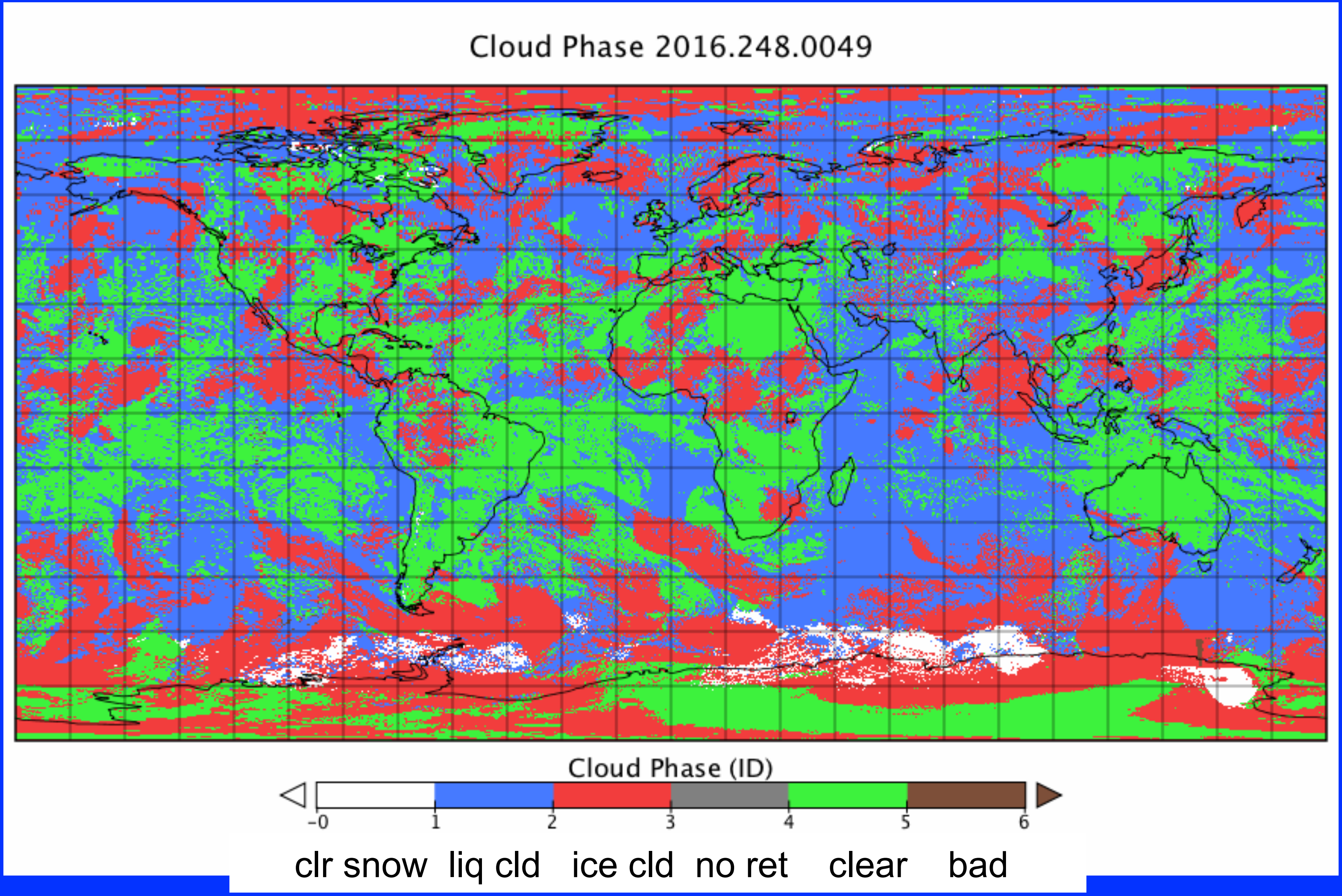
Generate EPIC composite to determine SW and LW anisotropic factors

- Use the scene type dependent CERES SW and LW angular distribution models (Su et. al. 2015);
- Scene type is defined based upon many variables: surface type, cloud fraction, cloud optical depth, cloud phase, cloud effective temperature, surface temperature, lapse rate, wind speed, etc. ;
- To determine the scene type for each EPIC pixel, high-resolution (5 km) cloud and radiance products are generated by merging retrievals from LEO/GEO satellites (Minnis et al. 2011, 2012) for the EPIC overpass time using an optimal algorithm to select the highest quality data available (nearest overpass time relative to EPIC observation, lowest viewing zenith angel);
- These high-resolution data are averaged into the EPIC pixels by accounting for the EPIC point spread function;
- Ancillary data from GMAO reanalysis and NSIDC are also included;
- Anisotropic factors for all EPIC pixels are derived using the scene type information provided by the EPIC composite and are averaged to provide the global means.

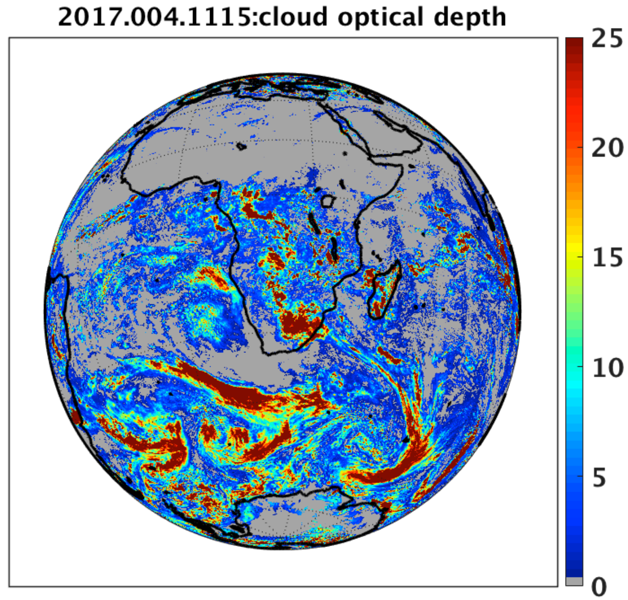
Global GEO/LEO composite data available on 5-km grid

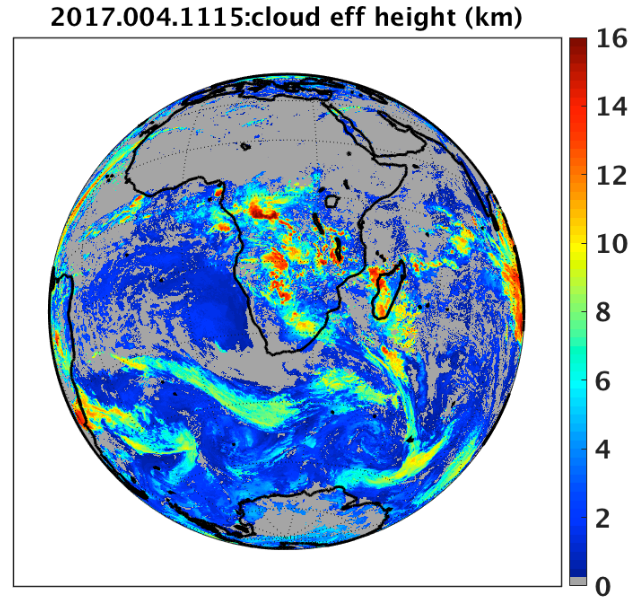


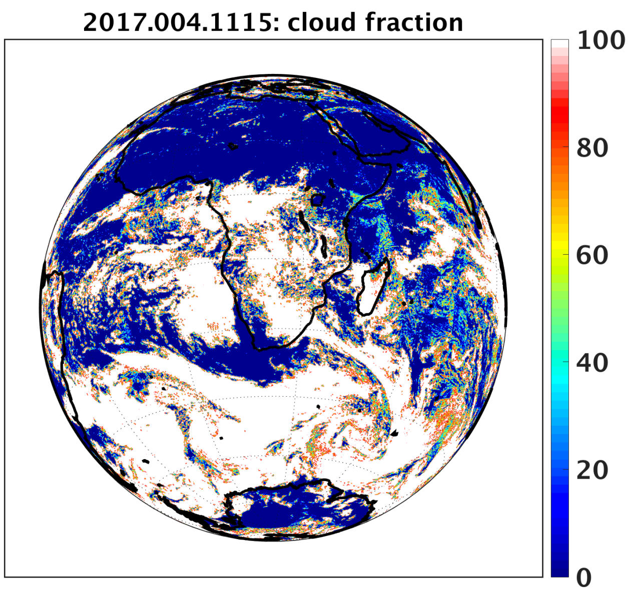
Cloud phase derived using high-resolution data

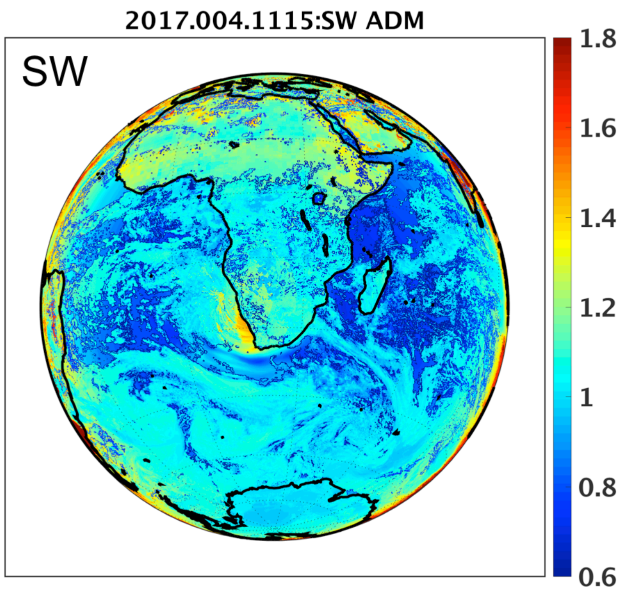


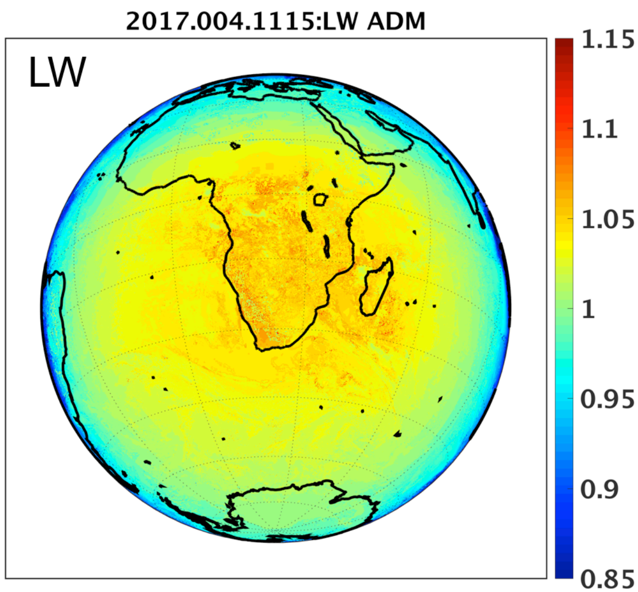
Cloud properties and anisotropic factors for 11:15 UTC, 4 Jan. 2017



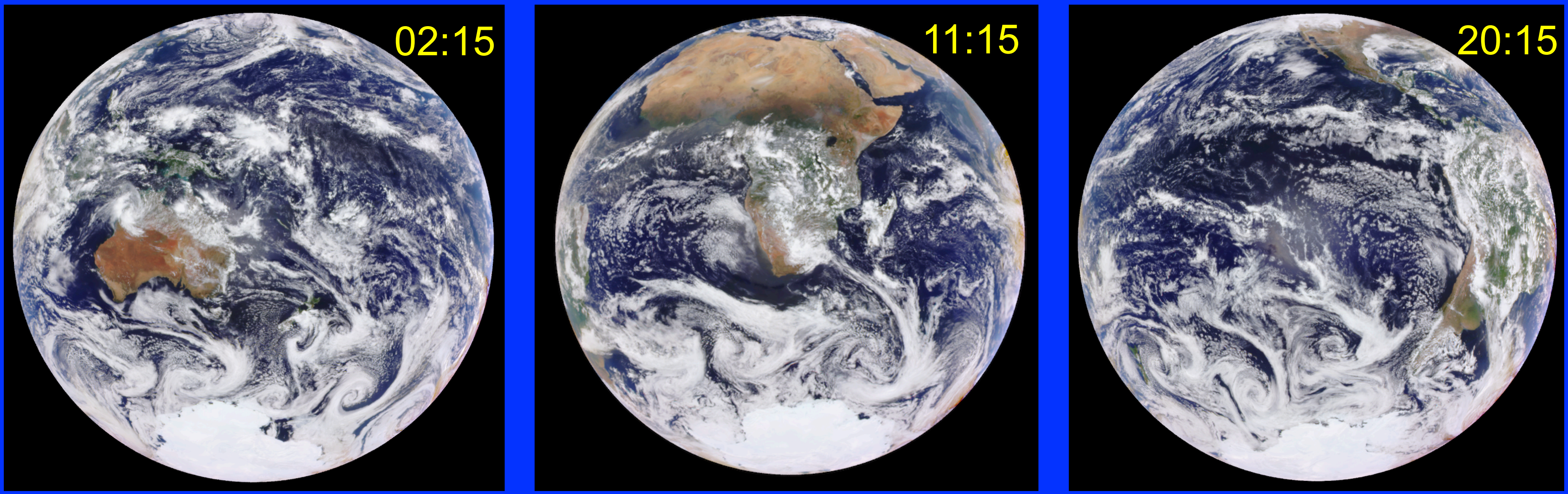


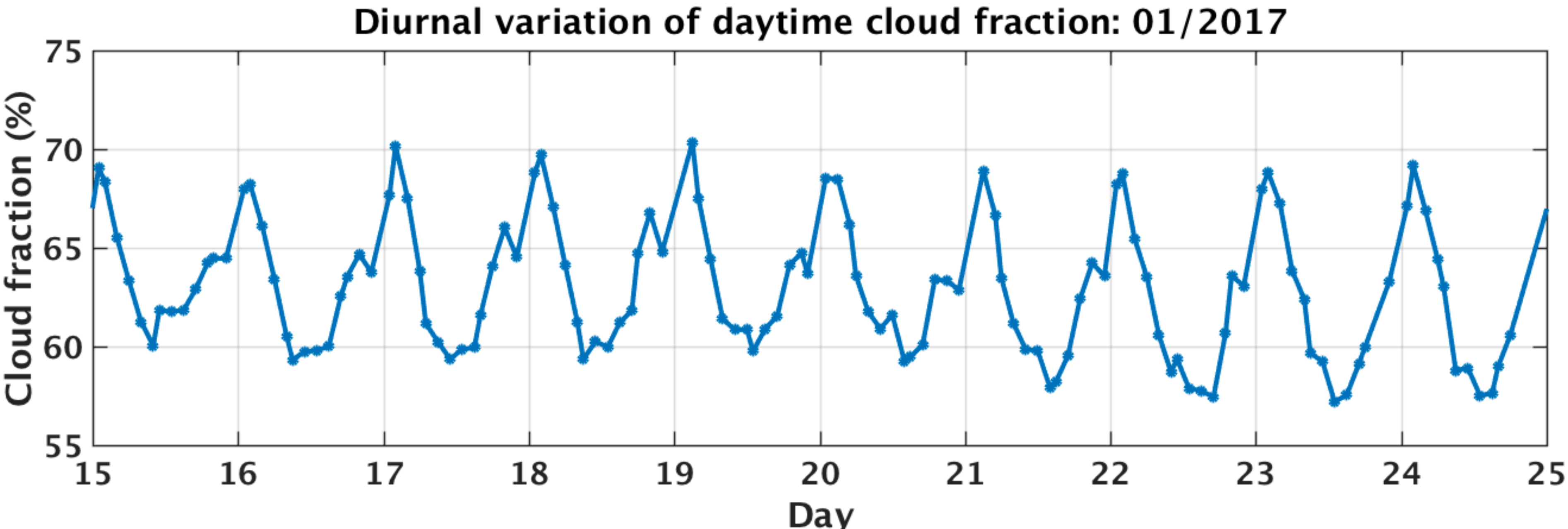




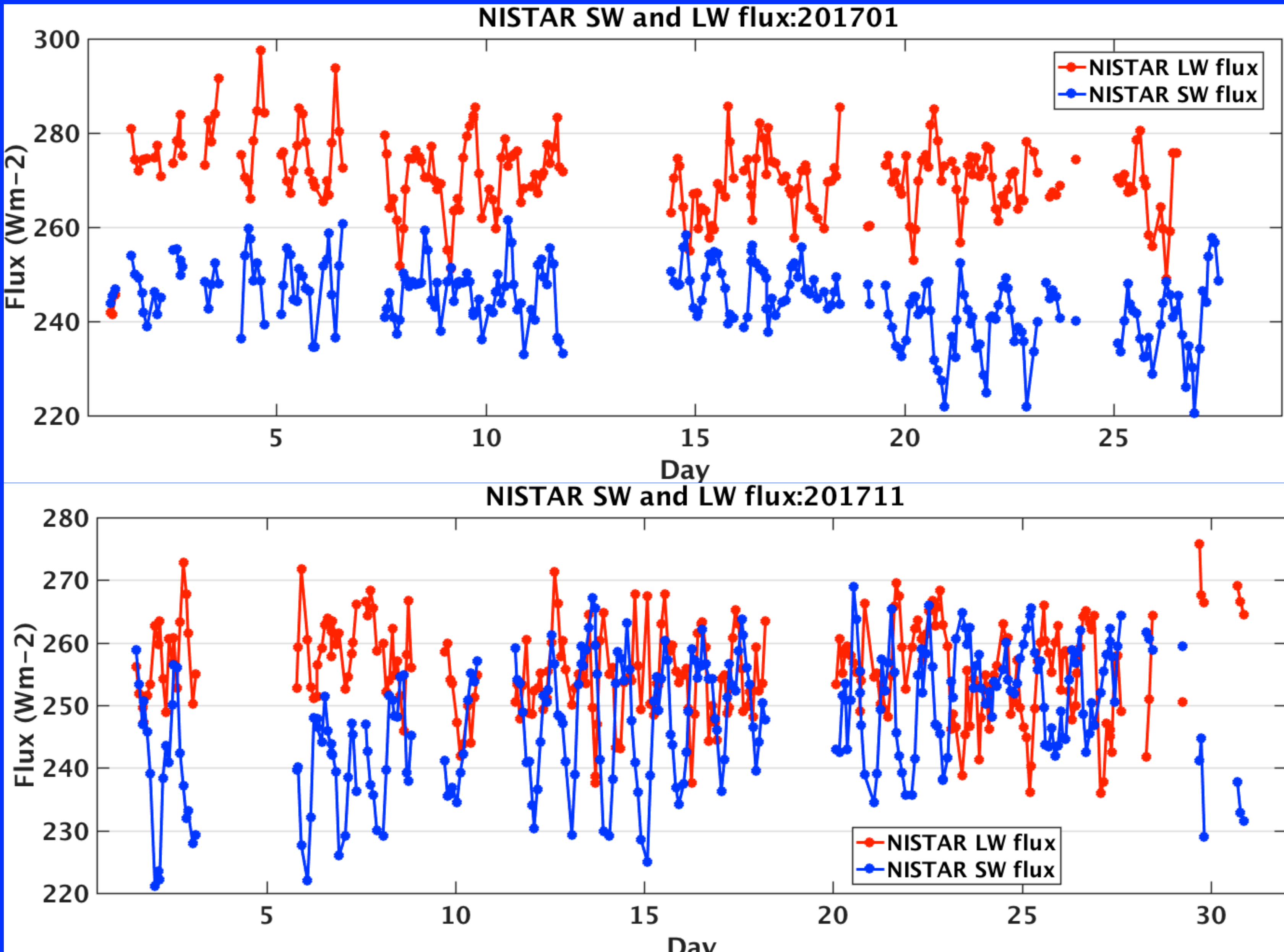


Diurnal variation of daytime cloud fraction





SW and LW fluxes from NISTAR

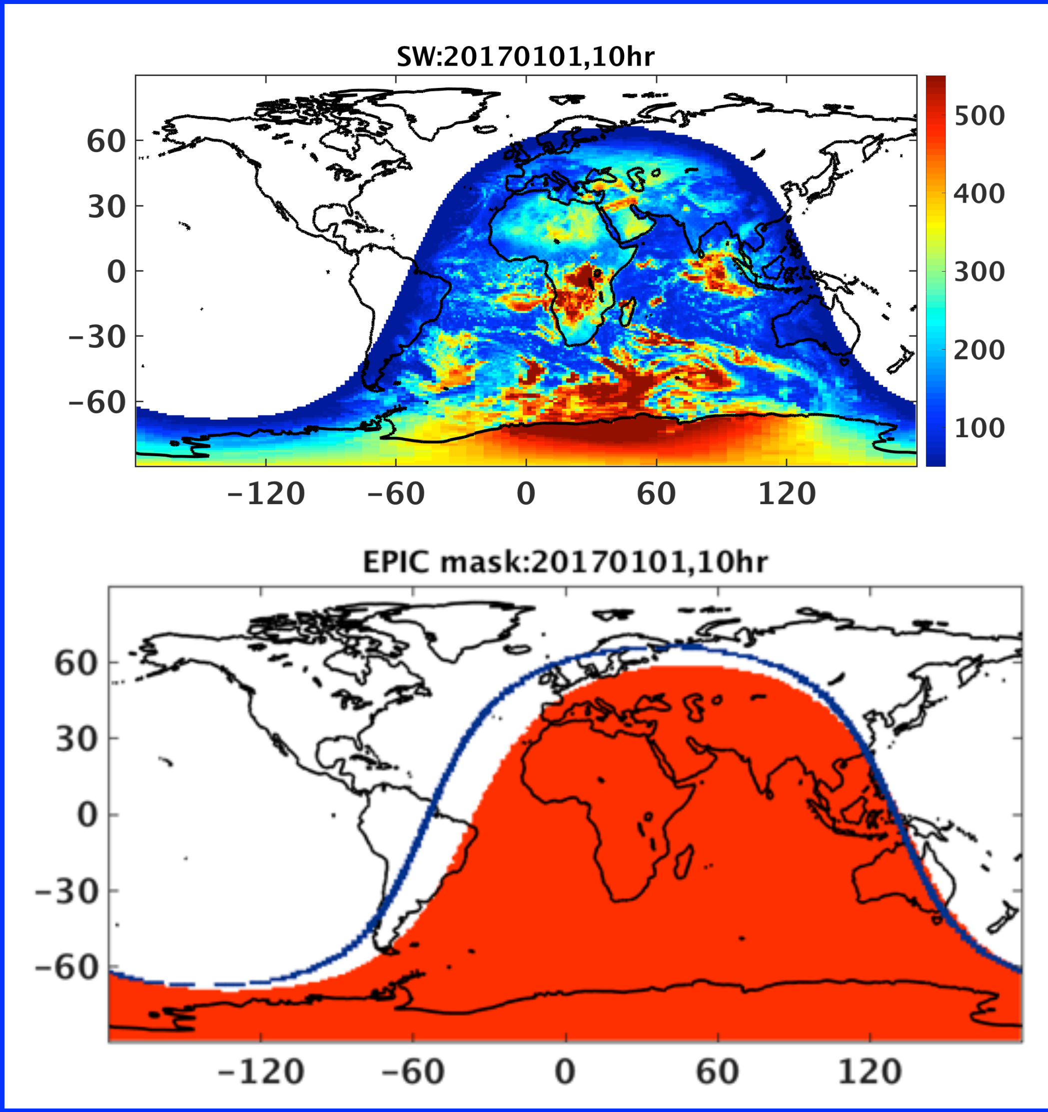


Comparison between NISTAR and CERES SYN fluxes

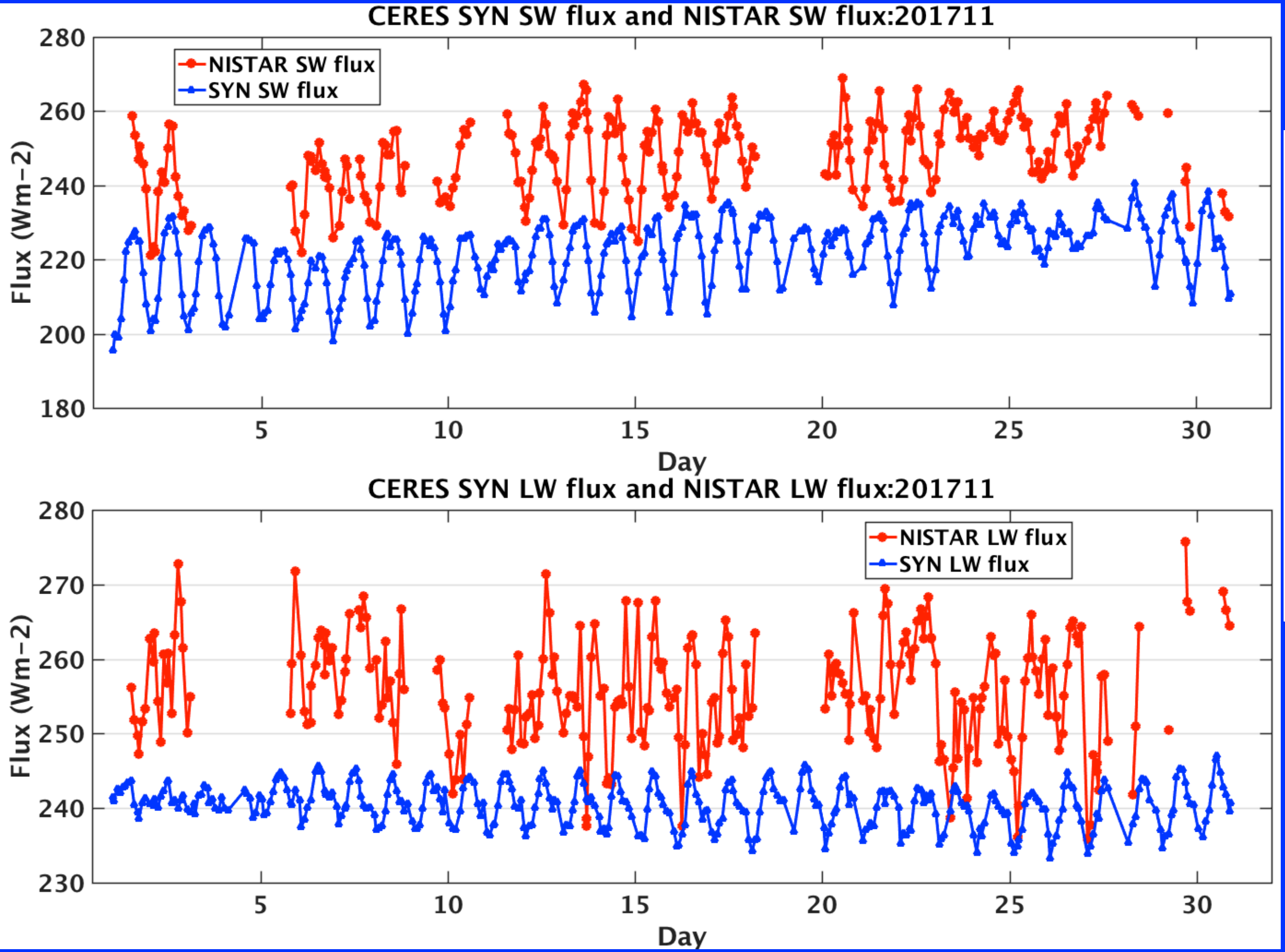
- CERES synoptic product (SYN) also provides hourly TOA SW and LW fluxes (Doelling et al. 2013);

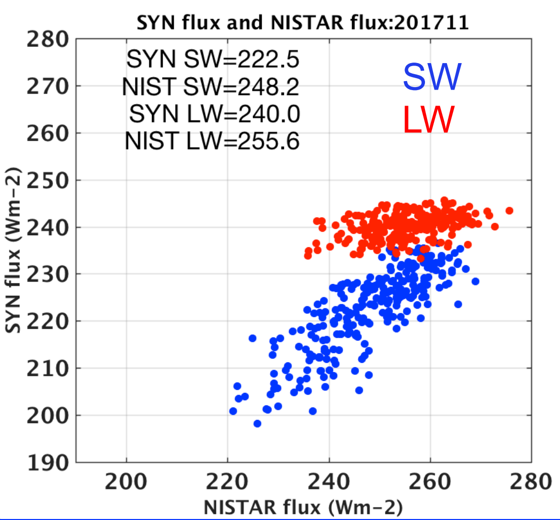
- To compare the hourly SYN data with the NISTAR data, only consider the SYN grid boxes that are visible to NISTAR, and these data are weighted by cos(latitude):

$$\overline{F_{syn}} = \frac{\sum F_j cos(lat_j)}{\sum cos(lat_j)}$$



Comparison between NISTAR and CERES SYN fluxes

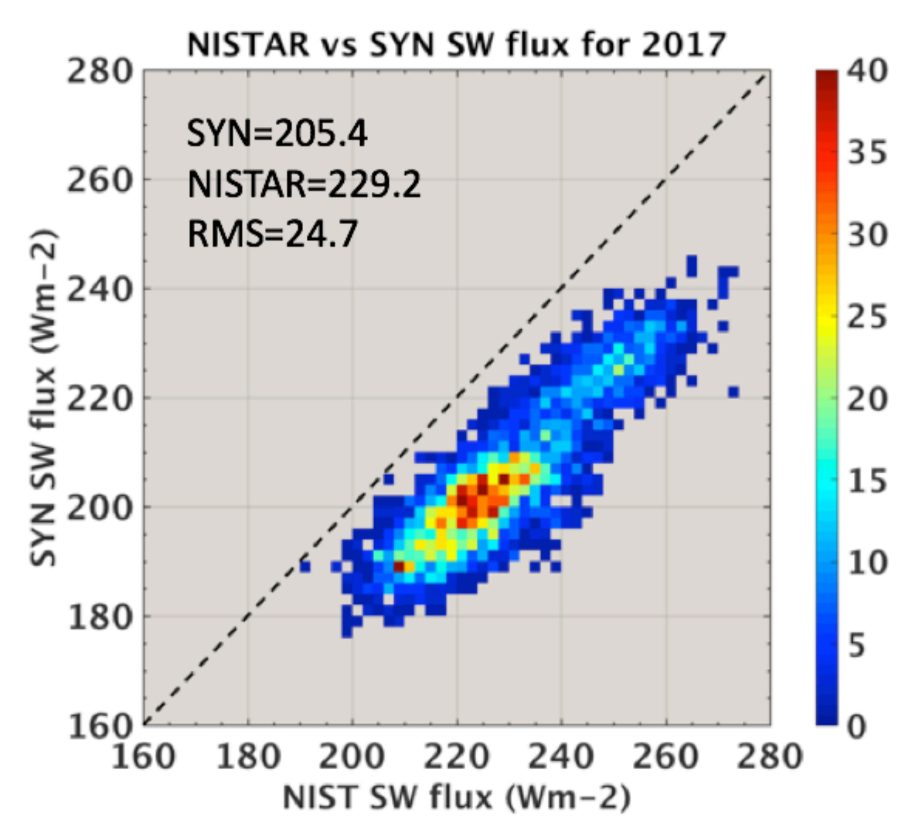




SW flux comparison between NISTAR and CERES SYN: 2017

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
F_s	220.1	210.3	205.2	201.8	201.3	198.8	193.9	194.9	200.2	210.5	222.3	228.5
F_n	245.0	229.3	226.0	220.7	224.2	225.8	219.2	218.8	222.4	235.4	247.9	252.1
$\frac{F_n - F_s}{F_s}$	11.3	9.0	10.1	9.4	11.4	13.6	13.0	12.3	11.1	11.8	11.5	10.3

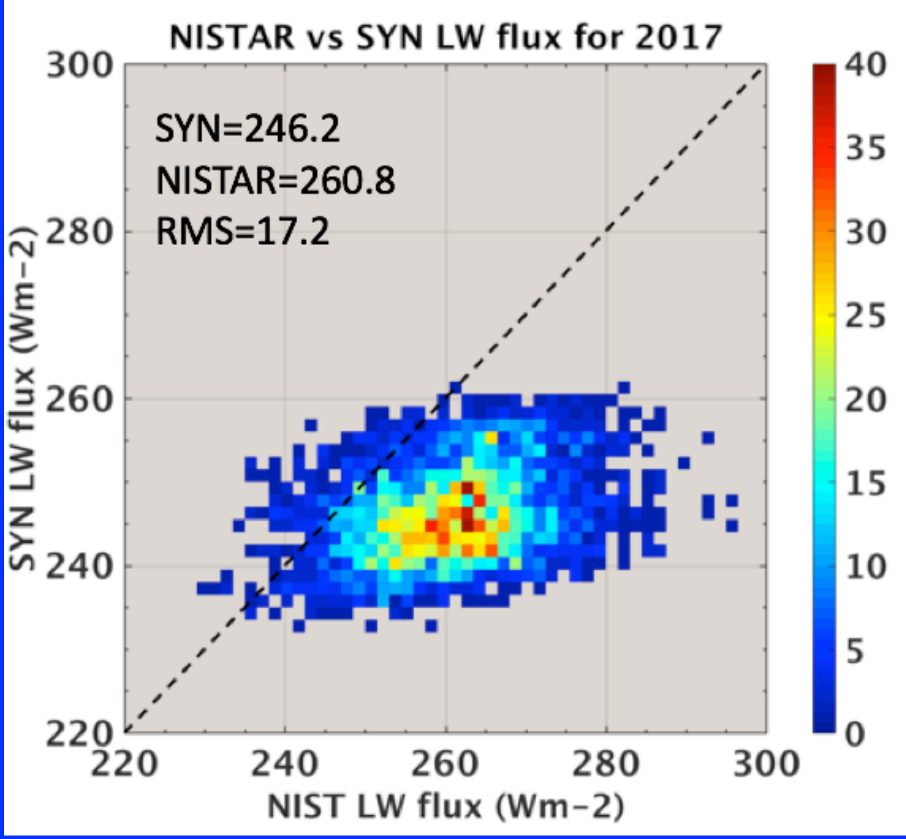
- The monthly mean NISTAR SW fluxes are greater than the CERES counterparts by 9.0% to 13.6%.
- Flux from NISTAR is highly correlated with SYN: r=0.89.



LW flux comparison between NISTAR and CERES SYN

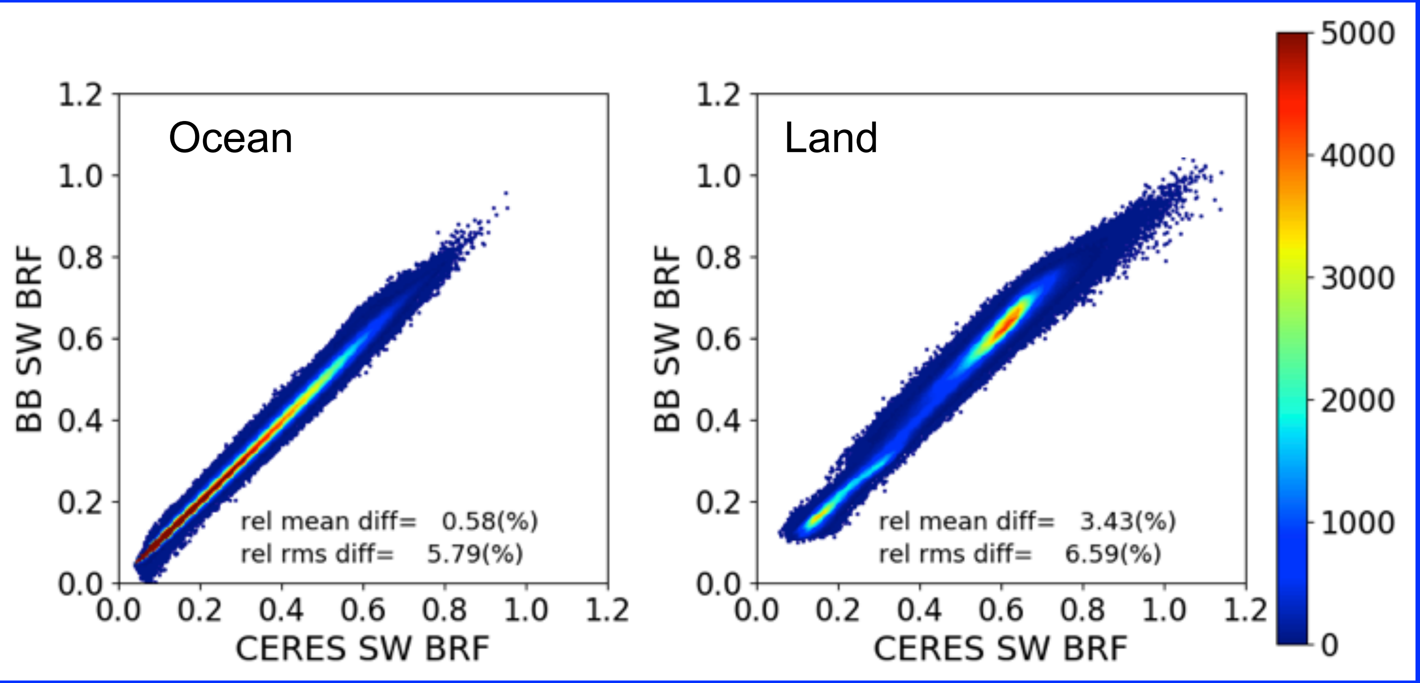
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
F_s	242.9	242.3	242.0	244.0	247.5	249.9	251.8	249.2	246.0	243.2	240.1	241.3
F_n	272.1	257.4	251.7	263.8	261.6	260.4	261.7	258.9	261.0	259.1	255.6	258.9
$\frac{F_n - F_s}{F_s}$	12.0	6.2	4.0	8.1	5.7	4.2	3.9	3.9	6.1	6.5	6.5	7.3

- The monthly mean NISTAR LW fluxes are greater than CERES counterparts by 3.9% to 12%. LW flux from NISTAR is poorly correlated with SYN: r=0.3.

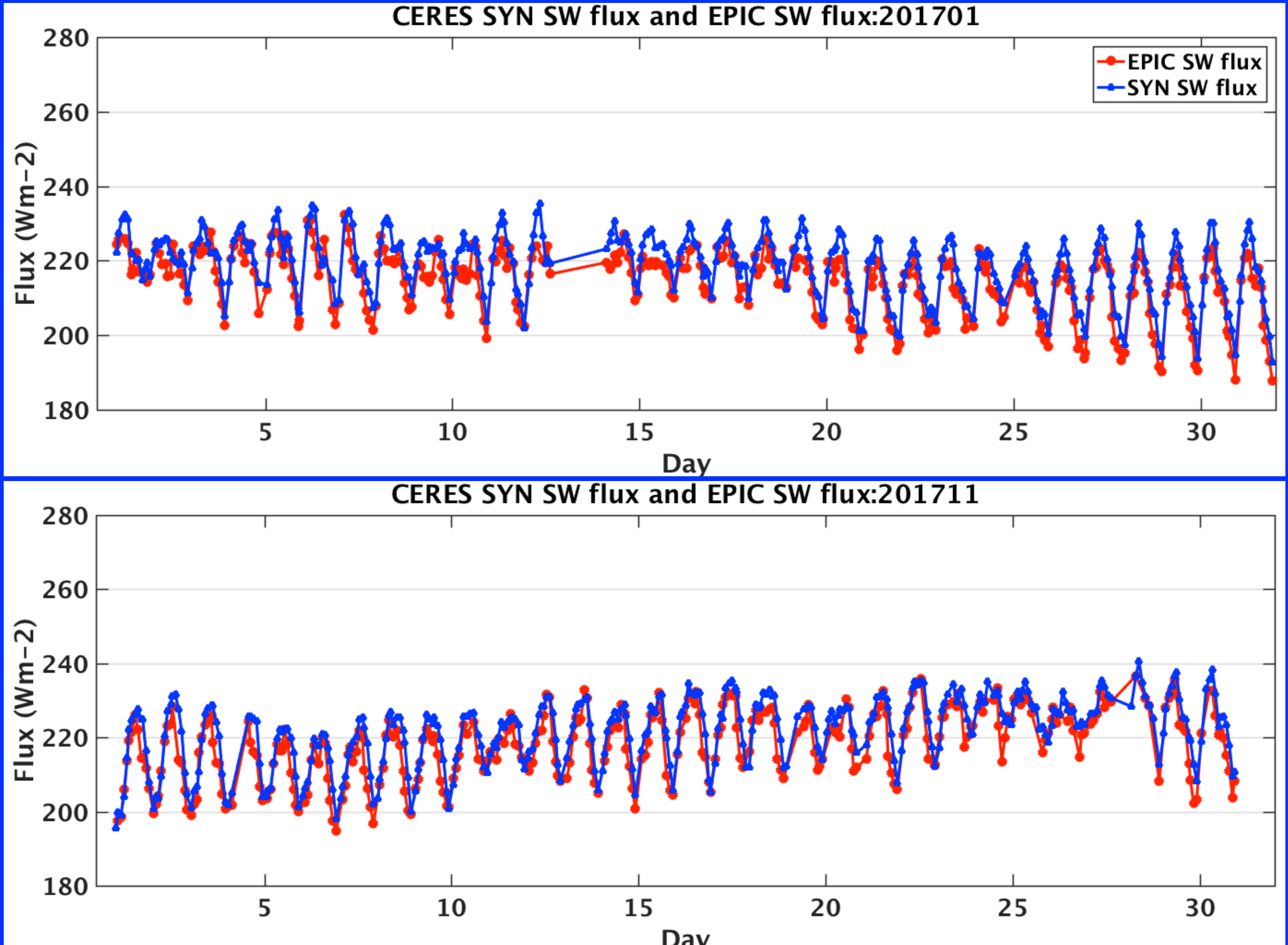


Derive broadband radiance from EPIC measurements

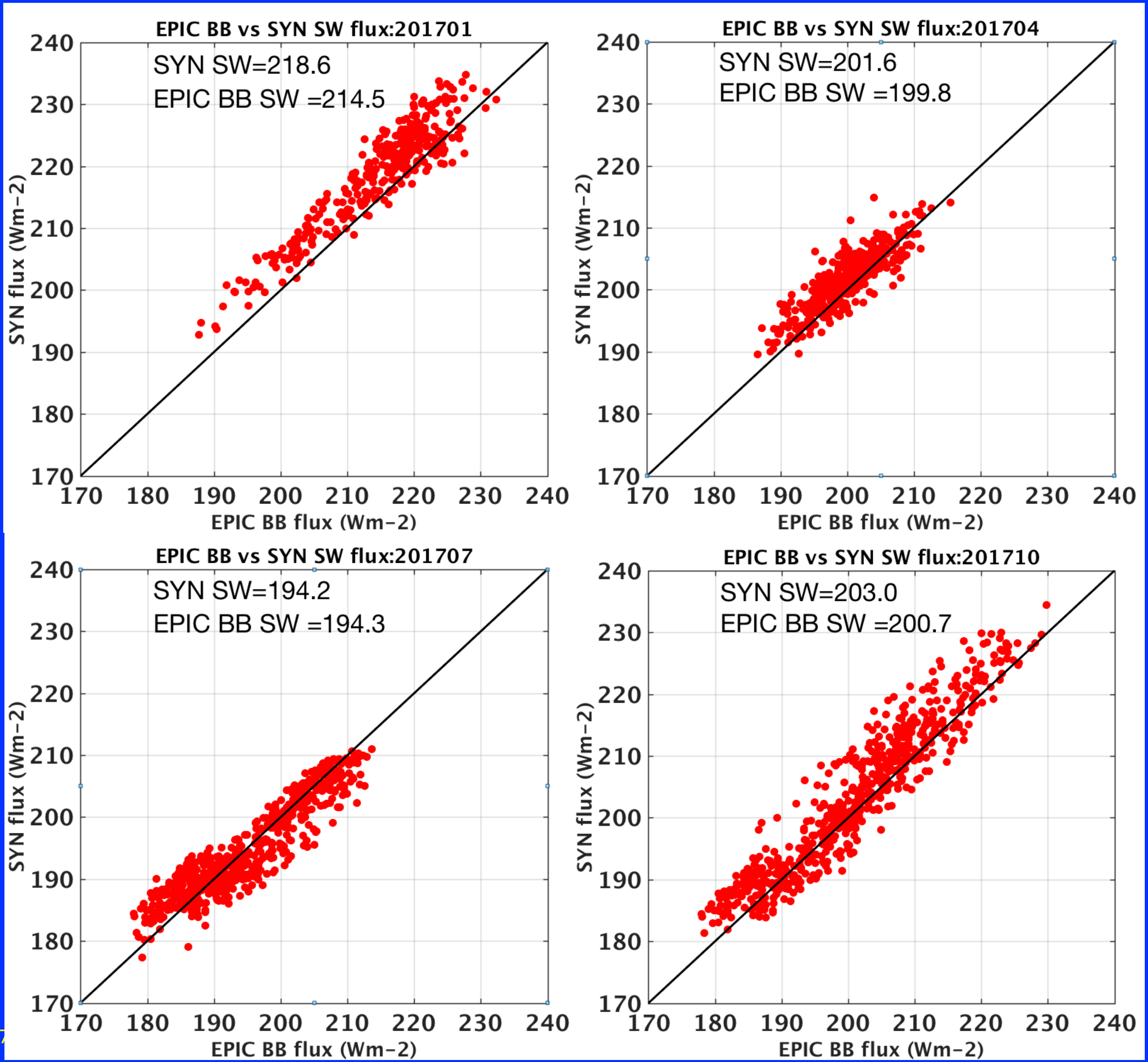
- Develop narrowband to broadband (NB2BB) relationships based upon collocated MODIS and CERES data for all-sky conditions separately for ocean and non-ocean surfaces using MODIS 469, 550, and 645 nm channels;
- Apply these relationships to EPIC 443, 551, and 680nm channels to derive EPIC broadband radiance (I^{e}_{bb});
- Average these pixel-level EPIC broadband radiance to produce global mean radiance ;
- Use the global mean SW anisotropic factor to convert the global mean EPIC-based broadband radiance to flux.

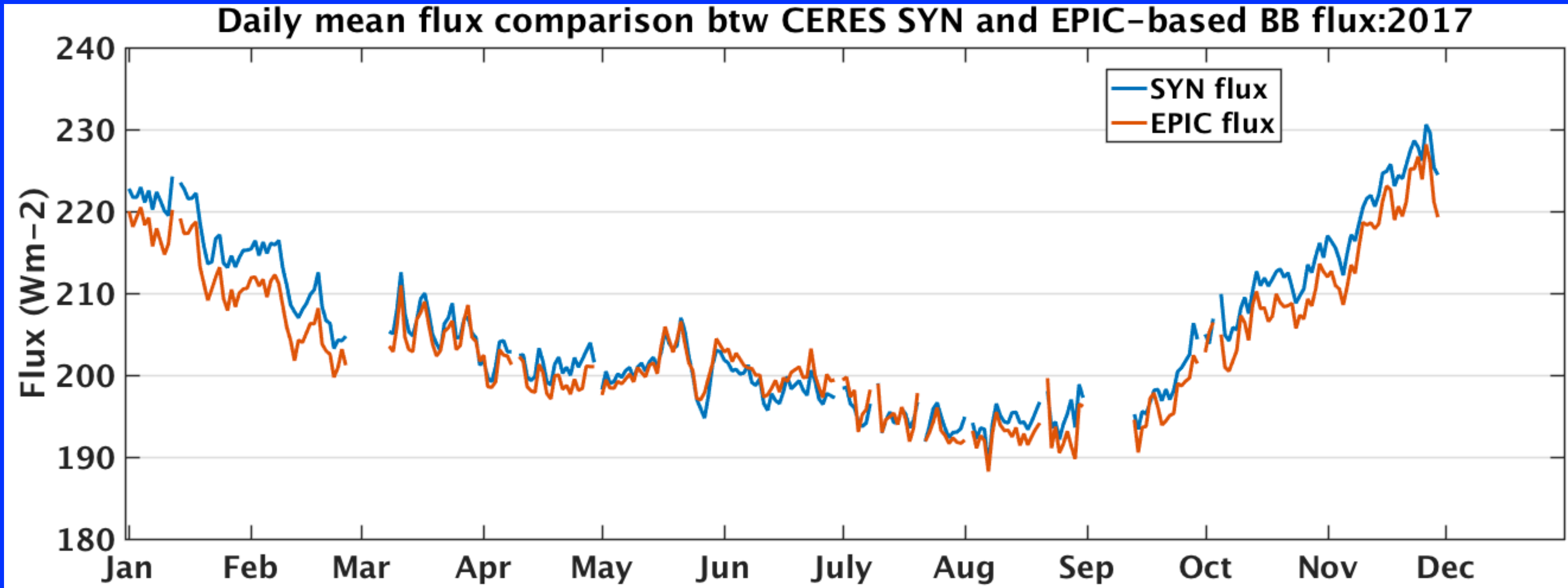


EPIC-based SW flux vs. CERES SYN SW flux

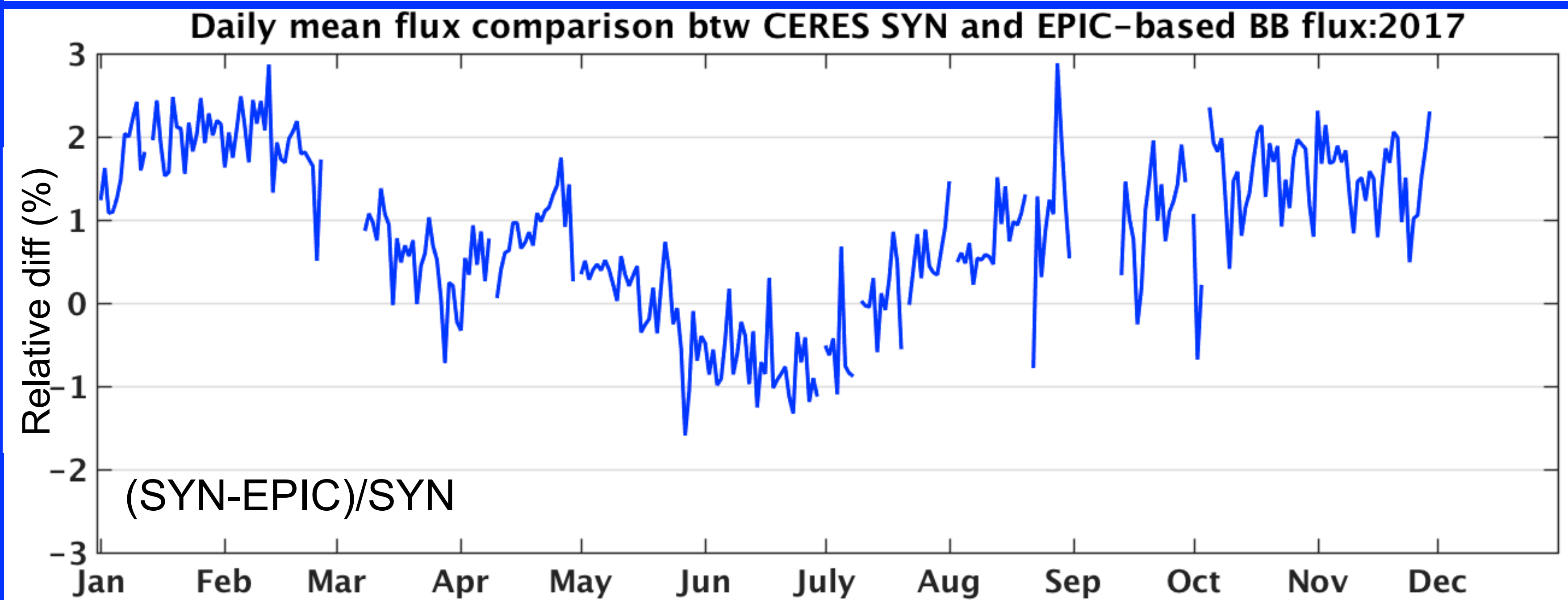


EPIC-based SW flux vs. CERES SYN SW flux





Daily mean flux comparison btw CERES SYN and EPIC-based BB flux:2017
SYN flux
EPIC flux
Flux (Wm-2)
240
230
220
210
200
190
180
Jan
Feb
Mar
Apr
May
Jun
July
Aug
Sep
Oct
Nov
Dec

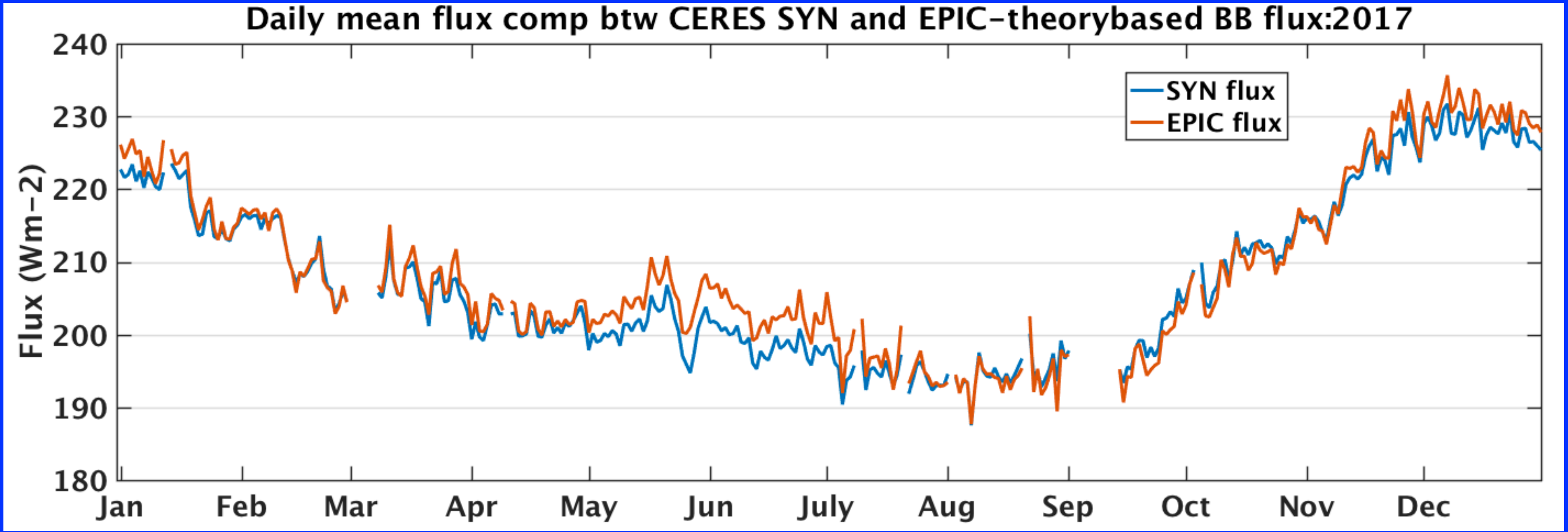


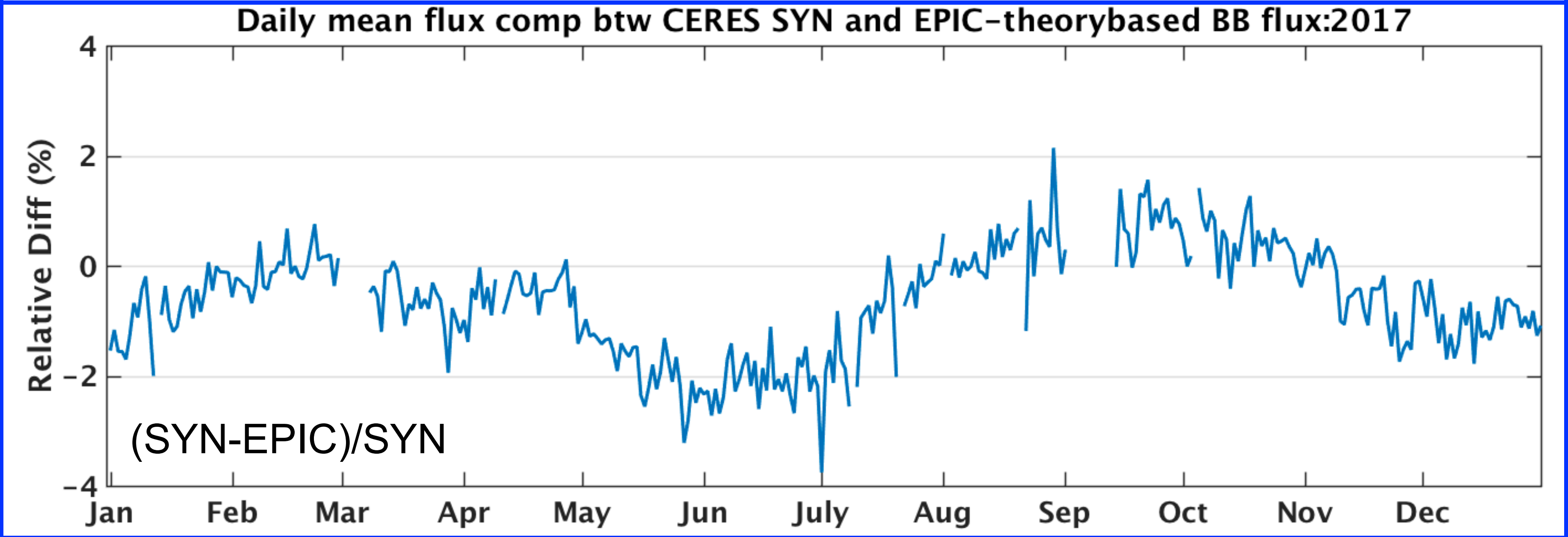
Daily mean flux comparison btw CERES SYN and EPIC-based BB flux:2017
Relative diff (%)
3
2
1
0
−1
−2
−3
(SYN-EPIC)/SYN
Jan
Feb
Mar
Apr
May
Jun
July
Aug
Sep
Oct
Nov
Dec

EPIC broadband radiance from theoretically-derived NB2BB coefficients

- Coefficients are derived separately for all-sky ocean and land
- For clear-sky, 8 different aerosol optical depths are considered
  - Over ocean, maritime aerosols with different wind speeds are used
  - Over land, continental average aerosols are used
- For cloudy-sky, different cloud optical depths are considered
  - Over ocean, 7 COD bins for both liquid and ice clouds, and considered 4 water effective radius and 4 ice effective diameter
  - Over land, 5 COD bins for both liquid and ice clouds, and considered 4 water effective radius and 4 ice effective diameter

Comparison of the EPIC SW flux derived using theoretical NB2BB coefficients with CERES SYN SW flux

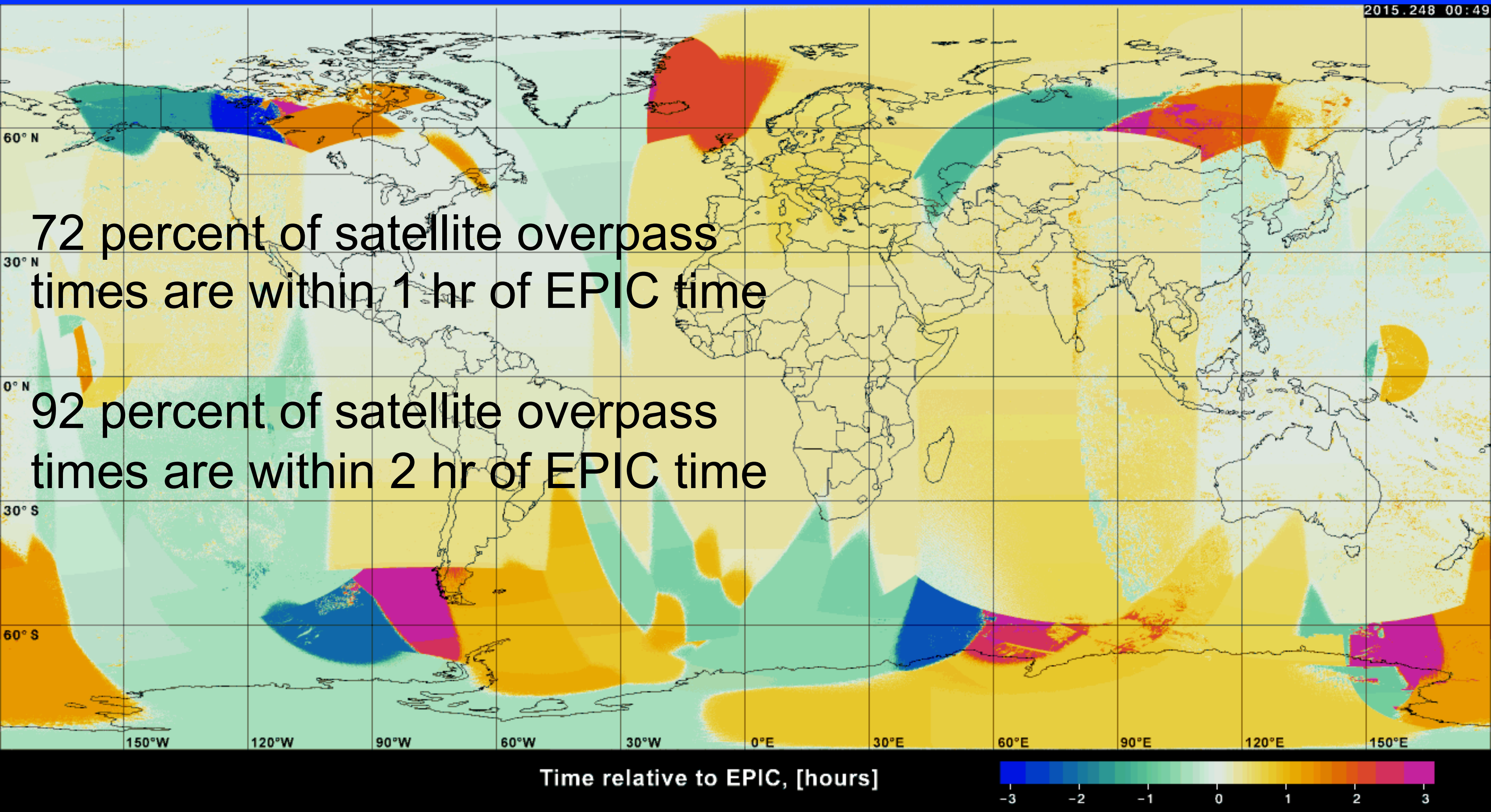




Summary

- EPIC composite data are developed to provide the scene identification for each EPIC pixel.
- Unfiltering factors are derived for the NISTAR SW/NIR channels.
- NISTAR SW fluxes are about 10.4% larger than those from CERES SYN data. Correlation coefficient is about 0.9 between them.
- NISTAR LW fluxes are about 5.7% larger than those from CERES SYN data, but they are poorly correlated (0.3).
- Narrowband-to-broadband relationships are derived to convert EPIC 443, 551, and 680nm radiances to broadband radiances, which are then used to produce global daytime SW fluxes.
- These EPIC-based SW fluxes agree with CERES SYN SW fluxes to within ±3%.

Relative time of satellite scans to reference (EPIC image time)



72 percent of satellite overpass times are within 1 hr of EPIC time

92 percent of satellite overpass times are within 2 hr of EPIC time

- Issues with INSAT infrared channels affects retrievals, replace with Meteosat-8